Summer Pruning Affects Yield and Improves Fruit Quality of 'McIntosh' Apples

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Abstract. The effects of summer pruning on the yield and quality of apples (*Malus domestica* Borkh.) from mature 'Rogers McIntosh'/M.7 trees were assessed in 1986-88. Summer pruning from 1 July through 1 Sept. enhanced red coloring and increased the percentage of the crop graded U.S. Extra Fancy. Fruit weight was not altered by summer pruning. Total yield was reduced by summer pruning only in 1 year, however, in no year was the harvested yield reduced. The portion of the crop that was picked in the first harvest was increased by summer pruning. Dormant-pruning time was decreased by summer pruning, and the total time required for pruning was increased only 1 of the 2 years where it was measured. Summer pruning and daminozide treatment significantly increased the estimated net returns.

'McIntosh' accounts for 58% of the New England apple hectare (Autio, 1989). Growers must wait for adequate color development before the beginning of 'McIntosh' harvest, since the U.S. Extra Fancy grade requires 50% of the surface to be a red that is sufficiently intense to be characteristic of the cultivar. Consequently, it is difficult to pick the entire crop before a significant portion abscises. Additionally, since all 'McIntosh' fruit do not color simultaneously, multiple harvests are required. 'McIntosh' growers have relied heavily on daminozide for preharvest abscission control and delay of ripening. Since daminozide is no longer available, other techniques must be used to allow growers to harvest a large portion of their crop meeting the Extra Fancy Grade.

Summer pruning is one horticultural practice that may assist growers in solving this difficult problem. Vincent (1917), Preston and Perring (1974), Stiles (1980), Lord and Greene (1982), Marini and Barden (1982), and Morgan et al. (1984) all showed increases in fruit redness as a result of summer pruning. This increase in red pigment was attributed to increased light penetration into the fruit-bearing portion of the tree canopy. Increasing redness by summer pruning may allow earlier harvest of 'McIntosh' as well as increase the portion of the crop reaching the Extra Fancy grade before abscission. However, decreases in fruit size have also been reported in some studies (Stiles, 1981; Marini and Barden, 1982; Myers and Ferree, 1983; Greene and Lord, 1983).

The objective of this study was to determine if summer pruning would enhance red pigmentation, thus allowing earlier harvest of Extra Fancy fruit and a consequent reduction in preharvest

drop. Additionally, we assessed the economic impacts of summer pruning.

Materials and Methods

All trees used in these experiments were trained to a central leader. Limb renewal in the upper one-third of the canopy was done during the dormant season to improve light penetration. Summer pruning consisted of thinning cuts made throughout the tree. Strong, upright branches, watersprouts, and shade-causing, hanging branches were removed. Horizontal branches were removed only if they caused significant shading to fruit below them. No branch with a diameter >2 cm was removed. No heading cuts were used, and, in general, cuts were not made in close proximity to fruit.

One summer pruning (Expt. 1). In 1986, 10 two-tree blocks (replications) of 23-year-old 'Rogers McIntosh'/M.7 trees were selected at the Univ. of Massachusetts Horticultural Research Center (HRC, Belchertown). One tree in each block was pruned on 21 Aug. A 30-fruit sample was taken and weighed on 9 Sept. Fifteen fruit were harvested randomly from the periphery of each tree in each block and 15 randomly from the interior. The percentage of red surface was assessed for each fruit, and the percentage of the sample making the Extra Fancy grade was determined. Commercial harvest began on 10 Sept. A commercial harvest crew picked the fruit from each tree, with the same individual harvesting both trees in a block. The crew was instructed to harvest only Extra Fancy fruit. A second harvest was made on 25 Sept. Yield for each harvest was recorded. All abscised fruit were collected after each harvest, and the "dropped" yield was recorded. The time required to prune each tree in the dormant season was recorded.

Pruning dates (Expt. 2a). In 1987, 15 six-tree blocks (replications) of 24-year-old 'Rogers McIntosh'/M.7 trees were selected at the HRC. A single tree in each block was pruned on

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1 or 15 July, 4 or 15 Aug., or 1 Sept. One tree in each block was not summer-pruned. The time required to summer-prune each tree was recorded. Fruit sampling and yield assessment for each tree were done as in 1986, except the fruit sample was taken on 9 Sept., while the harvests were on 15 and 28 Sept. The time required to prune each tree in the dormant season was recorded.

Expt. 2b. In 1988, the 1987 experiment was repeated in different trees at the HRC using eight blocks (replications) of 25-year-old 'Rogers McIntosh'/M.7 trees. The summer pruning dates were 1 or 15 July, 1 or 15 Aug., or 1 Sept. The fruit sample was taken on 16 Sept., and the harvests were on 17 and 27 Sept.

Pruning, growth regulators, economics (Expt. 3). A second experiment was conducted in 1988 to compare naphthalene-acetic acid (NAA), daminozide, and a control, with and without summer pruning. Seven six-tree blocks (replications) of 25-year-old 'Rogers McIntosh'/M.7 were selected at the HRC. Daminozide (1000 mg-liter⁻¹) was applied to two trees per block on 10 July. NAA (10 mg-liter⁻¹) was applied to two trees after the first harvest on 18 Sept. Two trees did not receive a chemical treatment. In each block, one of the trees receiving each growth-regulator treatment and a control tree were summer-pruned on 1 Aug. Pruning time was recorded for each tree. Yield assessments were performed as in the previous experiment, with harvests on 17 and 27 Sept. Twenty fruit were sampled at each harvest for flesh firmness, using an Effegi penetrometer (Effegi,

Alfonsine, Italy) with an 11.1-mm tip and one puncture per fruit (red side), and fruit weight determinations. Additionally, 20 kg of fruit were taken from each tree at each harvest, kept at 0C for 3.5 months, and graded. The time required to prune each tree in the dormant season was recorded. An economic analysis was conducted comparing the estimated net return of these treatments. A partial budget was constructed using values of U.S.\$0.79, \$0.63, \$0.42, \$0.13, and \$0.08 per kilogram for Extra Fancy, Fancy, Number 1, Utility, and processing grades, respectively (Porter, 1988). Production costs subtracted from the value of the crop included \$7/hr for summer and dormant pruning; \$185/ha for daminozide; \$20/ha for NAA; \$26/ha for the labor and equipment costs associated with spray application (Leahy et al., 1989); \$0.05/kg for harvesting and \$0.21/kg for storing and packing (M. Castaldi, personal communication).

All data were subjected to analysis of variance. When necessary, percentage data were transformed to arcsin before analysis. Where appropriate, means were separated by F test, Duncan's new multiple range test, single-degree-of-freedom linear comparisons, or orthogonal polynomial comparisons.

Results and Discussion

In all years the percentage of red surface and the percentage of a sample making the Extra Fancy grade were significantly increased by summer pruning (Table 1). In 1987, the five dates of summer pruning (1 July-1 Sept.) gave similar responses. In

Table 1. Effects of summer pruning on the fruit quality, fruit weight, yield, and pruning time of 'Rogers McIntosh'/M.7 trees (1986-88; Expt. 1-2b).

Summer pruning treatment	Red surface (%)	Extra Fancy (%)	Fruit wt (g)	Total yield per tree (kg)	Harvested yield per tree (kg)	Portion of total yield (%)		Pruning time per tree (min)		
						First harvest	Dropped	Summer	Dormant	Total
1986 ^z										
Control	49	42	---	240	168	59	30	---	17	---
21 Aug.	57	72	---	248	201	79	19	---	11	---
Significance	**	**	---	NS	**	**	**	---	**	---
1987 ^y										
Control	52	44	146	333	206	43	38	---	18	18
1 July	61	71	147	297	202	53	30	11	10	21
15 July	62	76	145	272	183	55	32	13	9	23
4 Aug.	64	76	150	287	191	57	31	15	9	23
14 Aug.	64	89	146	293	193	54	33	16	9	25
1 Sept.	61	73	144	308	198	55	32	16	10	26
Significance	**	**	NS	NS	NS	**	NS	**	**	**
Control vs. pruning	**	**	---	---	---	**	---	---	**	**
Among pruning ^x	NS	NS	---	---	---	NS	---	1**	q**	1**
1988 ^w										
Control	56	61	163	223	149	55	32	---	21	21
1 July	61	82	163	181	142	69	21	14	14	28
15 July	61	73	158	163	119	65	23	13	11	24
1 Aug.	68	92	160	161	123	67	21	13	10	24
15 Aug.	69	91	164	166	123	69	23	17	9	25
1 Sept.	67	92	164	163	127	66	21	12	10	22
Significance	**	**	NS	*	NS	*	*	NS	**	NS
Control vs. pruning	**	**	---	**	---	**	**	---	**	---
Among pruning ^x	1**	1**	---	NS	---	NS	NS	---	1*	---

^zValues for red surface are means of 300 observations, all others are means of 10.

^yValues for red surface are means of 450 observations, all others are means of 15.

^x1q: Significant linear or quadratic component, respectively.

^wValues for red surface are means of 240 observations, all others are means of eight.

**,*,NS Significant at *P* = 0.01, 0.05, or nonsignificant, respectively.

Table 2. Effects of summer pruning and growth regulator application on the yield of and pruning time for 'Rogers McIntosh'/M.7 trees (1988; Expt. 3).^{z,y}

Treatment	Total yield per tree (kg)	Harvested yield per tree (kg)	Portion of total yield (%)		Pruning time per tree (min)		
			First harvest	Dropped	Summer	Dormant	Total
Control							
Summer-pruned							
Control	185 a	119 b	55 a	34 a	10 a	18 b	28 a
NAA	191 a	125 b	48 a	33 a	10 a	22 a	32 a
Daminozide	204 a	142 a	53 a	29 a	10 a	18 b	28 a

^zWithin chemical treatment, mean separation by Duncan's new multiple range test ($P = 0.05$).

^yFor the pruning main effect, values are means of 21 observations. For the chemical treatment main effect, values are means of 14 observations.

^{*,NS}Significant at $P = 0.01$ or nonsignificant, respectively.

Table 3. Effects of summer pruning and growth regulator application on the quality and grade distribution of fruit from 'Rogers McIntosh'/M.7 trees and the estimated net return of the treatments (1988; Expt. 3).^{z,y}

Treatment	Fruit wt (g)	Flesh firmness (N)	Portion of the fruit sample (%)					Estimated net return (\$/ha, thousands)
			Extra Fancy	Fancy	Number 1	Utility	Processing	
Harvest 1	165 ^{NS}	65 ^{**}	91.1 ^{NS}	5.6 ^{**}	0.6 ^{**}	1.1 ^{NS}	1.6	---
Harvest 2	161 ^{NS}	58 ^{**}	90.0 ^{NS}	3.0 ^{**}	0.0 ^{**}	1.4 ^{NS}	5.6	---
Control	164 ^{NS}	62 ^{NS}	88.2 ^{**}	5.6 ^{**}	0.5 ^{NS}	1.2 ^{NS}	4.6	10.3
Summer-pruned	162 ^{NS}	61 ^{NS}	93.0 ^{**}	3.0 ^{**}	0.1 ^{NS}	1.3 ^{NS}	2.6	11.6
Control ^x	163 a	64 b	91.2 a	4.3 a	0.6 a	1.4 a	1.8 a	10.4 b
NAA	167 a	64 b	88.5 a	5.0 a	0.2 a	1.3 a	1.0 a	10.5 b
Daminozide	160 a	66 a	92.0 a	3.7 a	0.2 a	1.1 a	2.1 a	12.0

^zWithin chemical treatment, mean separation by Duncan's new multiple range test ($P = 0.05$).

^yWithin the harvest date and pruning main effects, values for fruit weight and flesh firmness are means of 840 observations, and all grade values are the means of 42 observations. The relative values are means of 21 observations. Within the chemical treatment main effect, values for fruit weight and flesh firmness are means of 560 observations, and all grade values are means of 28 observations. The estimated net returns are means of 14 observations.

^xFor firmness and the percent processing grade, the interaction of chemical treatment and harvest date was significant; so, the first and second column give the data from harvest date 1 and 2, respectively.

^{*,*,NS}Significant at $P = 0.01$, 0.05, or nonsignificant, respectively.

1988, the response became greater as summer pruning was performed closer to harvest. The apparent discrepancy between 1987 and 1988 data is related to the amount of regrowth that resulted from the summer pruning treatments. In 1987, terminal buds hardened early, so very little regrowth occurred from the early treatments, whereas, in 1988, bud hardening occurred later and enough regrowth occurred from the early treatments to reduce the light penetration to the fruit and thus coloring.

Fruit weight was not affected by summer pruning, even when pruning was done as early as 1 July (Tables 1 and 3). Summer pruning has been shown to reduce fruit size (Stiles, 1981; Marini and Barden, 1982; Myers and Ferree, 1983; Greene and Lord, 1983), but the effect has not been consistent. Greene and Lord (1983) found that summer pruning decreased the size of 'Cortland' fruit, but not of 'Delicious'. Morgan et al. (1984) found that only early season summer pruning reduced the size of 'Gala' fruit. Miller (1982) found no effect of summer pruning on the size of 'Delicious' fruit. These different results may be partially explained by differences in the location and severity of the summer-pruning treatment. Greene and Lord (1983) suggested that, as the severity of pruning increased or the distance between the cut and fruit decreased, the potential for a size reduction is enhanced. In our study, cuts were not made close to the fruit, and the intensity of the summer pruning was not severe.

Yield per tree was reduced by summer pruning only in 1988 (Table 2). This response was attributed to loss of some fruit during summer pruning and to the removal of some fruiting, hanging branches that were shaded. However, in no year was the quantity of harvested fruit reduced. In all years, the percentage of the yield harvestable during the first picking was increased significantly by summer pruning (Tables 1 and 2). In 1986 and 1988, summer pruning reduced the loss of fruit to drop by increasing the percent of the crop that was harvested before drop became severe. A direct effect of summer pruning on drop also may explain some of this reduction in loss. Marini and Barden (1982) showed that summer pruning decreased fruit abscission for 'Delicious' and 'Stayman' trees.

Although summer pruning represents an additional labor input, in all years it significantly reduced the time required to dormant-prune (Tables 1 and 2). Summer pruning increased total pruning time by an average of 30% in 1987, but not in 1988 (Tables 1 and 2).

Summer pruning did not affect flesh firmness in 1988; however, daminozide produced increased firmness for both harvest dates, while NAA reduced firmness (Table 3).

Summer pruning significantly increased the percentage of the crop in the Extra Fancy grade and significantly reduced that in the Fancy, No. 1, and processing grades (Table 3). Fruit from

the first harvest date showed no differences among the chemical treatments, but fruit treated with NAA from the second harvest date were more commonly graded into the processing category because of the excessive bruising of these softer fruit.

Summer pruning significantly increased estimated net return, as did the use of daminozide (Table 3). Summer pruning and daminozide increased net returns to a similar degree, 13% and 15%, respectively; however, it should be noted that daminozide did not control drop effectively in these trees in 1988. Daminozide may be expected to provide more economic benefit in years when it reduces drop significantly.

We have shown that summer pruning can significantly improve fruit coloring, allow more fruit to be harvested earlier, and reduce the losses to preharvest abscission. Pruning can be performed from 1 July to 1 Sept. in the climate of New England and in similar areas with similar benefits. This technique provides one means whereby apple growers can reduce the dependence on daminozide for 'McIntosh' production.

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Three-year-old Pecan Pollen Retains Fertility

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Abstract. Stored pollen from pecan [*Carya illinoensis* (Wangenh.) C. Koch] was analyzed for in vitro germination, fertilization efficiency, Goal fruit ret, and characteristics of mature fruits. We demonstrate pecan pollen can be stored for several years and set fruit. Pollen stored for 1, 2, and 3 years at - 80C and 1 year at - 196C retained the capacity for fertilization. Pollen stored at - 196C was more viable than pollen stored at - 80C, with no significant correlation between length of storage at - 80C, as judged by fruit abortions during the second drop. Final fruit set was not affected by pollen storage conditions, except for pollen collected in a season of drought. Fruit set is a more reliable indicator of pollen viability than in vitro germination. With two minor exceptions, fruits produced with stored pollen were similar to those developing after pollination with fresh pollen.

Flowering within pecan is heterodichogamous. As a result of this developmental pattern, temporal differences exist both within and among cultivars for maturity of staminate and pistillate flowers. The degree of dichogamy may vary among seasons and locations (Smith and Romberg, 1940; Sparks, 1987). This reproductive mechanism sometimes results in the need for reserve supplies of viable pecan pollen for experimental breeding and commercial mass pollination programs. In breeding programs,

artificial maintenance of functional pollen over long periods would allow for crosses between cultivars with flowering extremes. Functional pollen stored for 1 year would be required to hybridize a cultivar with early pistillate flower receptivity (e.g., 'Moneymaker') with pollen from a cultivar whose staminate flowers mature late (e.g., 'Stuart'). In addition, prolonged pollen survival may serve as a means for long-term conservation of genetic material in pollen banks (Towill, 1985). Such germ-plasm preservation strategies can be efficient, economical, and space-saving, and these methods may be suitable as a supplement to more classical preservation systems using seeds and vegetative material.

In commercial pecan orchards, growers could mass-pollinate when pollen is limiting (Bennett et al., 1986). Like the breeder,

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